Plant Nematode Investigations in Japan
—Results and Problems—

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A great contribution to the knowledge of plant parasitic nematodes in this country has been mostly achieved only within the last ten years. Before describing the results of the research so far revealed, it should be briefly explained what initiated the research project of the nematode control on a nation-wide scale.

Around the year of 1955, the agricultural administration began to endeavor efforts for raising field crop production that had been rather neglected until then, and attention was drawn to nematodes that prevent efficient crop production. The Ministry of Agriculture and Forestry established the Nematode Research Laboratory in the National Institute of Agricultural Sciences in 1958, and employed a new staff of nematode investigators who were assigned to each prefectural agricultural experiment station according to the 5-year nematode control program starting in 1959. The staff began to examine soil samples taken from nursery beds, fields and orchards in the prefecture.

Nematode Systematics

One of the most remarkable results achieved by the nematode control program as mentioned above is that a large number of nematode species have been found spread all over the country. The number of nematode species recorded before the commencement of the program amounted to less than ten, but it has increased to as many as more than one hundred species including some unidentified ones.

Of the root-knot nematodes, at least five species, *Meloidogyne hapla*, *M. incognita*, *M. arenaria*, *M. javanica* and *M. thamesi*, have been found. Of the cyst forming nematodes, six species of the soybean cyst nematode *Heterodera glycines*, *H. oryzae*, *H. avenae*, *H. trifolii*, *H. humuli* and *H. cacti*, and of the root lesion nematodes, more than eight species including *Pratylenchus penetrans*, *P. coffeae*, *P. vulnus*, *P. loosi* and so forth, have been recorded in Japan. Of the so-called ectoparasitic nematodes, about 30—40 species are counted including the stunt nematodes *Tylenchorhynchus* and *Tetylenchus* spp., the pin nematodes *Paratylenchus* spp., the spiral nematodes *Helicotylenchus* and *Scutellonema* spp., the ring nematodes *Criconema*, *Criconemoides* and *Hemicriconemoides* spp., and the stubby root and dagger nematodes *Trichodorus* and *Xiphinema* spp. There seem to be several new species among them. Thirty genera and 36 species of nematode which are especially important in this country have been given Japanese common names. Abundant populations of *Hirschmanniella* spp. have been always found infested in every piece of rice paddy fields throughout Japan.

The fact that so many species of plant nematodes are newly discovered within a few years explains that most injuries caused by them have been certainly overlooked for a long time. Therefore, for controlling nematode injury, it must be of most importance to realize the nematode injury itself.

Nematode Damage to Crops

Nematode injuries to annual crops can be commonly judged from the nematode species and its population level around the root. Even if a high population of nematodes is detected, however, it is sometimes difficult to prove the relationship between the nematode and its effect on the plant, particularly on perennials, because it is a common rule that there exists a certain length of period between nematode attack and the manifestation of injury by the plant. This period seems particularly longer ,sometimes may be extending for several years or more, on such a plant that exhibits low sensibility to nematodes and has a long life. Another reason for the difficulty of estimating nematode injury to perennials is the fact that, like a relationship between a citrus tree and the citrus nematode, there is none of tree which has no infestation of the nematodes, and consequently, such a nematode-infested tree has long been thought to be a "standard" of plant vigor, yield, longevity, and so forth. Fortunately, a newly developed nematicide, dibromochloropropane (DBCP), which can be applied even to the established crops without any phytotoxicity, has partly proved to what extent nematodes can damage such perennials.

It is generally observed that the root-knot nematodes considerably reduce the yield of sweet potato, peanut, celery, fig, peach and others, while the cyst nematodes reduce that of soybean, Azuki bean and upland rice, and the root lesion nematodes, yields of great burdock, sweet potato, taro and many other crops. In addition to the reduction in yield of various crops, nematodes cause destructive injury to root vegetables such as carrot, radish, great burdock, sweet potato, yam, ginseng, sugar beet, and so forth by reducing their quality as commercial products.

Perennial trees and shrubs like fruit trees, tea, mulberry, garden trees, rose, azalea and so forth weaken their plant vigor by nematode parasites and eventually shorten their plant life. A good example was seen in a case of fig trees grown in Hyogo Prefecture in 1959. At a fig plantation near Osaka where it was common practice to replant every 9 to 10 years in the belief that their yields came to the peak at 5 or 6-year old and dropped suddenly after eight. DBCP applied to 5-year old trees obtained satisfactory control of nematodes with an increase in yield. Differences were also distinct in plant vigor, number of leaves, size of leaf, and length of internode. More interesting was that the treated plants showed no sign of decline after the eighth year. This convincingly demonstrated that plant nematodes not only affected yields but shortened plant life.

It has long been said in this country that 7 years should be elapsed until next cropping of watermelon, egg plant, and pea, while 5 or 6 years for tomato, red pepper, and burdock, 3 to 4 years for musk melon, melon cucumber, taro and kidney bean. This is explained from that successive cropping makes the land tired so much as to afflict crops with so-called soil sickness. Soil sickness is also evident on perennials such as peach, citrus, loquat, grapevine, persimmon and chestnut. As a result of the nation-wide examination of nematodes, it seems very likely that nematodes play an important role in the occurrence of the soil sickness or replant hazard. A low productivity of flax in a certain area in Hokkaido was evidently caused by the pin and root lesion nematodes against the common belief that it had been induced by excessive soil moisture. Failure of the successive planting of rush at the same nursery in Hiroshima and that of upland rice in Kanto District have proved that the spiral nematode and the rice cyst nematode respectively had been the causal agent. Soil sickness of burdock in Kanto- and that of taro in Kansai Districts were discovered to be due mainly to the root lesion nematode, because the removal of the causal organism with soil treatment evidently lessened the trouble. The replant problem is best known to peach producers, and large populations of the root lesion nematode, the pin nematode, and the root-knot nematode are always detected from peach orchards. The majority of tea plants at Makinohara in Shizuoka have been cultivated for nearly forty years. However, as the growers began to replace the older trees, most of the seedlings were slow to mature. Their roots were found infested with a high population of nematodes.

It has been proved that black rot of Japanese radish caused by *Xanthomonas campestris* (PAMMEL) DAWSON is introduced by the root-knot nematode infection. There must be many cases in which occurrence of disease so far considered to be a single pathogen are proved associated with nematode species. The dagger nematode was discovered for the first time to be a vector of fan-leaf virus on grapevine in California. In Japan, there seem several cases in which the dagger and the stubby root nematodes play an important role in transmitting plant viruses, evidences of which have just appeared here and there.

Nematode Control Measures

When the 5-year nematode control program was initiated in 1959, it was attempted to produce nematicides within the nation, to enlarge the demand for them, and to reduce their prices. This aim was achieved only in a few years since, and yet the chemical treatment does not pay on such crops as wheat, barley, soybean, and potatoes which produce comparatively less profit. The soil treatment is made mostly by vegetable producers, occupying about 60 percent of the total treated area over the country which is roughly estimated at 30,000 ha. Among vegetables, cucumber is the largest followed by carrot, Chinese cabbage, tomato, radish, watermelon, spinach, burdock, egg-plant and cabbage. Soil treatment is also becoming common for cultivations of tobacco, devil's tongue, yam, ornamental flowers, strawberry, and so forth. Dibromochloropropane treatment is gradually expanding among growers of mulberry, tea, apple, peach, fig, grapevine and persimmon, partly because of the government subsidy given to it.

Each species of the root-knot nematodes found in Japan has a wide range of host plants and, therefore, a rotation with nematode immune crops is difficult to carry out. Even though it is the case, a crop that suffers comparatively little damage from this nematode should be selected for the rotation. New let's turn our attention to a case seen at Yachimata in Chiba Prefecture, the biggest peanut producing area in Japan. In this area, the northern root-knot nematode *Meloidogyne hapla* is widely distributed, inflicting serious losses to the growers. However, as the nematode species does not affect sweet potato, watermelon, wheat, barley and upland rice, the rotation of peanuts combined with those resistant crops has long been adopted to avoid the increase in the nematode population in the soil. The crop rotation practice at Yachimata shows that identification of nematode species is so important that the species tells the growers what kinds of crops are safe or dangerous, or that with what kinds of crops a rotation should be set up to avoid the nematode injury. In other words, an intensive work should be carried out in order not only to find if any parasitic nematodes are associated with the plants, but also to know to what species it belongs.

Differences among varieties in the resistance to the root-knot nematode *Meloidogyne incognita* are evident on sweet potato; Norin No. 5, Taihaku, Norin Nos. 3, 7, 9 are all resistant, while Kanto No. 14 and Norin No. 1 rather susceptible. It is also true that Norin No. 5, a highly resistant variety, is very susceptible to the root lesion nematode *Pratylenchus coffeae*. The problem is thus so complicated. "Nema-shirazu" is a soybean variety highly resistant to the soybean cyst nematode. This was bred from an indigenous variety "Geden-shirazu" by Ishikawa and his co-workers at Kariwano Crop Experiment Station, Akita Prefecture. Extensive studies on the nematode trapping fungi carried out so far have proved that such fungus species are widely distributed in crop fields in Japan.

Chemical treatment for controlling nematodes has been considerably improved during the last several years. D–D mixture or ethylene dibromide of 2 or 3 ml is normally injected 15 cm deep at 30 cm intervals. This basic procedure can be made with hand injector or power injector mounted on a cultivator or tractor. Before application of the chemical, the field should be evenly plowed and levelled. Instead of overall treatment of the field, fumigant can be applied to only rows or holes set up for planting. For instance, the row treatment is made by injections of one to three stripes between ridges on which wheat is grown, and such crop as vegetables, Chinese yam, or peanut is afterwards planted between the ridges. For planting with wide spacing like watermelon, pumpkin, seedling of fruit tree, and garden tree, the chemical is applied to only the planting site 1 to 2.5m in diameter according to the plant species, at the rate of 4 to 5 ml per injection, 20cm deep, at 30cm intervals. After a certain period from injection, plowing should always be made to remove the vapor out of the soil. The length of time between application and plowing is determined mainly depending on the soil temperature, and this is normally a week in summer and 2 to 3 weeks in spring and autumn. In summer, the soil should be watered immediately after the application in order to keep the vapor in the soil as long as possible.

A 1: 1,000 or 2,000 aqueous solution of DBCP emulsifiable concentrate is evenly applied to trenches or concentric circles set up at the base of tree, up to 10—15cm deep, at the rate of 3 to 7ml of the chemical per square meter. Soil is immediately put back after application. For plants that are grown on ridges, like fig, tea, and mulberry trees, the chemical is applied to trenches 10-15cm deep positioned on both sides of a row of trees. DBCP granules are also available and usually applied in the same way as the emulsifiable concentrate. Another application method is an even broadcasting of the chemical onto the surface, being followed by plowing. When orchards have a cover crop, an injection or drench with DBCP emulsifiable concentrate is preferable. The best trial result is secured with the high dilution of emulsifiable concentrate. This may be due to the better dispersion of the chemical in the soil and the limited concentrations around the roots, although ample water supply is needed. Dosage rates of DBCP will vary with plant specsel· It seldom exceeds 10 g active ingredients per square meter. The recommended dosage in. Japan is, 4g for mulberry, 7-8g for fig, tea, grapevine and citrus, and 10g for peach and apple. For ideal dispersion of DBCP, soil temperature must not be below 15 °C and the period from May to September is favored. Specifically for fig, May to early June; for peach, April to May; for apple, May or October; for pear, May to June or from September to October; for citrus, July to September; for tea, May to October; and for mulberry, middle to late April or from middle to late June.

A field once treated can hardly remain safe from nematodes for several years, and accordingly, a rotation of crops should be taken up as much as possible to minimize nematode damage and to prolong the duration of effectiveness.

Photosynthetic Characters and Fertilizer Response of Rice Varieties

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It is said that the varietal difference in fertilizer response, especially in nitrogen response, of rice plant is concerned with not only resistance to disease or lodging, but also physiological and morphological characteristics.[1] Meanwhile, factors contributing to dry matter production as well as the rate of photosynthesis per unit leaf area are easily influenced by nitrogen. Therefore, experiments were carried out to investigate the relationship between the photosynthetic characters and the nitrogen response of rice varieties.

Efficiency in dry matter production

Dry matter production is, in principle,